Replacing the Hierarchy of Engineering Qualifications and Roles

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***Abstract*— There are generally three types of engineering qualification offered around the world, corresponding to the three commonly recognized engineering roles: engineer, technologist, and technician. This paper examines how the definitions and standards applied to the different engineering roles and qualifications implicitly (and sometimes explicitly) suggest a hierarchy, with engineer identified as superior to the other two roles. This hierarchical thinking undervalues the technologist and technician roles, and gives the false impression that the engineering role (and the corresponding qualification) incorporates the knowledge and abilities of the technologist, which in turn simply builds on the technician. In fact, as explored here, the roles are complementary and should be considered equally important and valuable in an engineering endeavor. A new model based on the CDIO framework is presented which highlights the superiority of each engineering role in a different aspect of an engineering process. This framework will guide the development of the corresponding qualifications in preparing students appropriately, and will hopefully help discredit the hierarchy of engineering roles.**

***Keywords*—engineer; Washington Accord; technologist; Sydney Accord; technician; Dublin Accord; CDIO framework; engineering roles**

I. Introduction

Around the world, different professional engineering and accreditation bodies have identified different engineering roles in professional practice which are in turn linked with differentiated tertiary qualifications in engineering. Due to the unique education provided by engineering qualifications, individuals wishing to practice engineering in a professional capacity are frequently required to complete the corresponding qualification type. Alternate paths to professional registration are available in some countries, but are often pursued only in unusual circumstances. In recent years, there has been increasing interest in enabling international mobility of engineering professionals, which has in turn inspired interest in the equivalence of the engineering qualifications. Under the auspices of the International Engineering Alliance (IEA), various engineering associations from around the world have agreed to three international accords to recognize substantially equivalent academic qualifications. These qualifications are classified according to the formal professional engineering role for which a graduate qualifies. Though specific professional titles vary from country to country, the most common terminology is the following:

- Engineering Technician (Dublin Accord)
- Engineering Technologist (Sydney Accord)
- Engineer (Washington Accord)

In this paper, we will explore how the historic and contemporary definitions of the three engineering roles have led to a hierarchy of roles, usually suggesting the superiority of the engineer and inferiority of the technician. The hierarchy is implicit in numerous contexts, including the qualification standards detailed in the IEA agreements. We then present a new model which conceptually correlates each of the engineering roles with the appropriate aspects of engineering activity without suggesting a hierarchy. Understanding of the role is essential to developing appropriate pedagogical and curricular approaches to engineering education. The new framework can also serve as a basis for future divisions of engineering work as roles continue to adapt.

Throughout this paper, we will refer to the different academic qualification/graduate/student by the corresponding engineering role. Hence, a “technologist qualification” is any qualification that can lead to eventual registration as a professional engineering technologist, a “technologist graduate” is a graduate of such a program, and so on.

II. Engineering Roles and Qualifications

The diversity of engineering roles evolved naturally from the increasing complexity and diversity of engineering work. As technology advanced and industry proliferated, the knowledge and skill required to pursue an entire engineering task grew beyond the abilities of a single individual. This effect is illustrated in Fig. 1, adapted from a 1977 paper by McCollom [1], showing how engineering education first shifted to expand emphasis on science and mathematics, then introduced the technician and technologist qualifications to fill the ever-widening realm of engineering work. In the following decades, the expansion has continued to include and incorporate computing and information technology across all the roles.

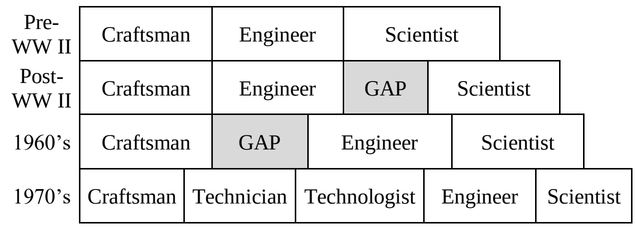

Fig. 1. The evolving scope of engineering roles in the 20th century, adapted from [1].

Around the world, different authorities and engineering organizations produced different structures to train engineering professionals across this spectrum of roles, usually based on the existing educational structures and regulatory environment. Most authorities require an appropriate engineering qualification from a tertiary institution for each role and further specify a quantity and type of training before one can be recognized as a practicing professional in that category.

Though the nature and breadth of engineering practice is generally aligned around the world, international comparisons and benchmarking is often difficult due to the different structures and policies. Not all countries and authorities recognize or differentiate between the three engineering roles. Often, in order to guarantee international mobility of graduates, an academic institution might apply for accreditation by an authority from another country. The US-based Accreditation Board for Engineering and Technology (ABET), for example, currently accredits programs at 118 non-US institutions [2].

TABLE I. ENGINEERING QUALIFICATION STRUCTURES FROM INTERNATIONAL ENGINEERING ALLIANCE ACCORD SIGNATORIES

	Qualification type		
	Technician (Dublin)	***Technologist (Sydney)***	***Engineer (Washington)***
Australia	2-year program	3-year program	4-year program
Canada	2-year program	3-year program	4-year program
Hong Kong	---	2-year program	4-year program
Ireland	2-year program	3-year program	5-year program *
New Zealand	2-year program	3-year program	4-year program
South Africa	3-year program **	1-year program ***	4-year program
South Africa (new programs)	2-year program	3-year program	4-year program
South Korea	2-year program	3- or 4-year program	4-year program
Taiwan	---	4-year program	4-year program
United Kingdom	Apprentice-ship	3-year program	4- or 5-year program *
United States	2-year program	4-year program	4-year program

* May consist of multiple qualifications or one integrated qualification.

** Two taught years plus a mandatory year of workplace-based learning.

*** Requires completion of a three-year technician qualification

Seeking greater international mobility for graduates, a number of accreditation authorities agreed in the Washington Accord to mutual recognition of engineer qualifications; later the Sydney and Dublin Accords did the same for technologist and technician qualifications, respectively [3]. These Accords set requirements for substantial equivalence of engineering qualifications and guaranteed mutual recognition of those qualifications. Though relatively few countries are signatories to more than one Accord, those countries provide a basis for comparison of the three qualification types, and we will confine our attention to those countries.

Table I provides a summary of the various engineering qualification types and general qualification structures for the countries signatory to multiple Accords. Note that the technologist qualifications are the most structurally diverse, with expected academic programs ranging from a one year add-on up to four years. The diversity of structures in the technologist qualifications is related to an inconsistent understanding of how to define and value the role of the engineering technologist, which we shall explore next.

III. A PERCEIVED (OR EXPLICIT) HIERARCHY OF ROLES

A significant problem with the definition of the three engineering roles is the seemingly inevitable ranking. Though authors of policy and research are usually careful to note the contributions of each, there is a persistent tendency to present the engineering roles as a hierarchy, with "engineer" paramount.

This is not a recent criticism: Schallert in 1973 noted that the then-standard model (reproduced in Fig. 2) "tends to represent the theorist as the superior citizen and the craftsman as the substandard citizen" [4]. (His comments were in the context of proposing technologists as best-suited for management positions; it is unclear if his proposal gained any traction.) Schallert went on to present a new framework for envisioning the engineering roles, recreated in Fig. 3, which in fact does an admirable job of placing the roles within the spectrum of theory and skill without suggesting a "superior

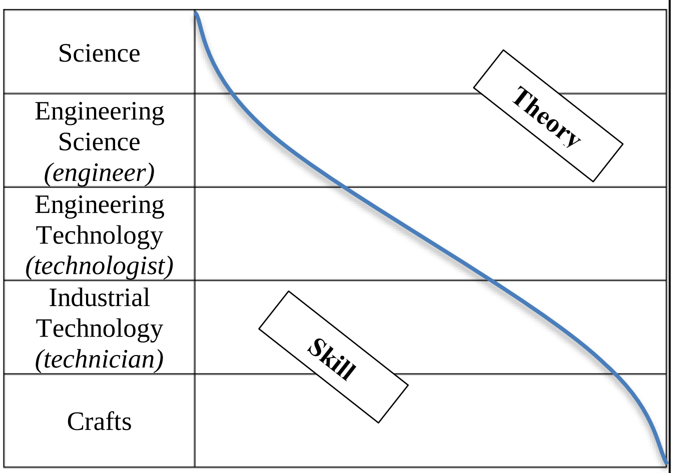

Fig. 2. The "classic model … (A.E. Peterson, 1965)" adapted from [4].

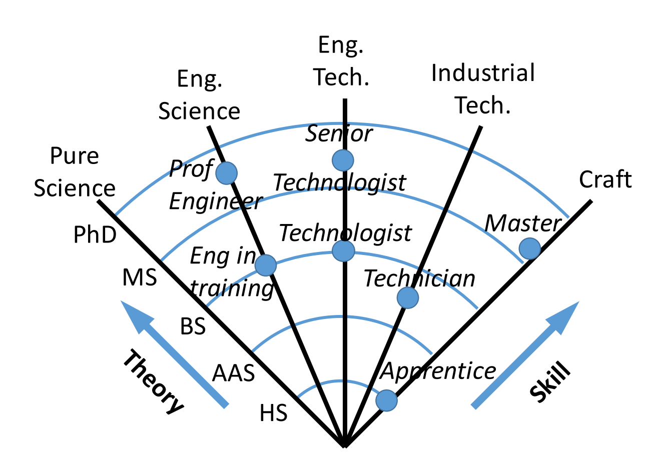

Fig. 3. The "Technological Personnel Spectrum Map" of [4], adapted.

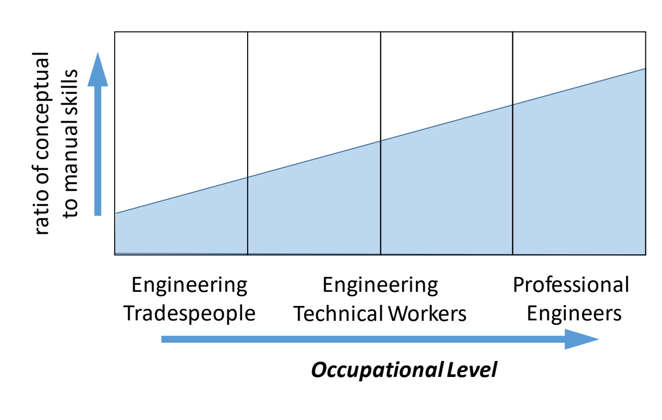

Fig. 4. The engineering occupations, adapted from [5]

citizen." However, Schallert's model was not widely adopted, and more common descriptions continued to follow the trend of implying the engineer's superiority, such as the one shown in Fig. 4 from an Australian non-profit research report of the mid-1980s [5]. The latter example is notable for the "occupational level" arrow, again denoting a hierarchy.

The previous examples were introduced to demonstrate the long-standing tendency of various parties "rank" the engineering roles, but the historical flavor should not be taken to mean that the tendency has ceased. On the contrary, both the language and attitude persist and have been alarmingly consistent over the years. Consider, for example, the following definition of engineering technology from the American Society for Engineering Education's 1962 evaluation criteria for technician qualifications:

> Engineering technology is that part of the engineering field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational area between the craftsman and the engineer at the end of the area closest to the engineer. [6]

This definition served for decades as the ABET definition of engineering technology (encompassing both technician and technologist roles and qualifications), is still widely used – a simple internet search will provide numerous examples. Note that engineering technology is delegated to supporting engineering activities. In at least one more recent (2002) introductory engineering textbook, the technologist, technician, and craftsman are termed "engineering support personnel" while the engineer is the "designer" and "leader" at "the top of the spectrum" [7]. Though the same text goes on to mention blurred boundaries between roles, the overall message pervades: engineer on top/in charge, technologists, technicians, and craftsmen given authority in that order. A far cry the technologist-as-manager envisioned by Schallert.

Some organizations go further than the implied hierarchy of engineering roles. For example, the American Society of Civil Engineers definition of a civil engineering technologist includes the phrase "…while working under the direct control and personal supervision of a [professional civil engineer]," and likewise a civil engineering technician "…works under the direct control and personal supervision of a [professional civil engineer] or direction of a [civil engineering technologist]" [8]. This explicit hierarchy is not arbitrarily specified, but is motivated by the degree of legal responsibility each team member is allowed to assume. However, the rigid structure clearly defines the superiority of the engineer over the other roles.

It is noted that the discussion has been dominated by references to US definitions and discussions. The majority of published discussions and research on the engineering roles were driven by the rapid economic development in the US during and after World War II. Many other nations took cues from the US discussion and terminology. In the UK, on the other hand, one finds early recognition that the technologist (called "technician engineer" and later "incorporated engineer") should not be seen as inferior to the professional engineers ("chartered engineers"). Consider the language of Bromfield in 1969, and contrast with the stratified US discussion:

> Technician engineers are at the top of the whole range of technician engineering manpower…. The work of the technician engineer is complementary to that of the chartered engineer; the one works alongside the other. The technician engineer is an engineer in his own right: he has an identity and career of his own…. The technician engineer … may carry technical and managerial responsibility either independently or under the supervision of a chartered engineer or scientist. [9]

What a contrast to the contemporary writings in the US! And, though incorporated engineer status is now frequently seen as a stepping-stone to chartered engineer status, the more positive impressions of the technology roles persist in UK society.

IV. An Implied Hierarchy of Qualifications

To enable the comparison of quite diverse qualifications, the three Accords are defined in terms of graduate attributes and knowledge profiles expected of students earning these qualifications [10]. Different classes of general engineering problems and activities are classified according to the appropriate qualification type and graduate role. This outcomes-based approach enables comparison of the diverse

TABLE II. WORDS USED IN IEA RANGE OF PROBLEM SOLVING TO DIFFERENTIATE ENGINEERING GRADUATE ATTRIBUTES [10]

Engineer	***Technologist***	***Technician***
"…complex…"	"…broadly-defined…"	"…well-defined…"
"…wide-ranging … issues…"	"…variety of factors…"	"…several issues…"
"…outside problems encompassed by…"	"… partially outside problems encompassed by…"	"…encompassed by…"
"…diverse groups of stakeholders…"	"…several groups of stakeholders…"	"…limited range of stakeholders…"
"…require judgement…"	"…require judgement…"	---
"…diverse…"	"…variety…"	"…limited…"
"…multi-disciplinary settings…"	---	---

qualification structures described in Table I in terms of the graduates produced. These graduate attributes and associated definitions form the basis for all of the signatory-bodies accreditation standards, and have thereby become the de facto standard for characterizing an engineering qualification.

Probably in an understandable effort to standardize and differentiate between the three qualification types, most of the contextual definitions in the IEA Accords are almost identical across the three qualification types, differing only in the range of problems addressed or the type of activities considered. Therein lies a problem, as the terminology used to distinguish between the qualifications suggests the selfsame hierarchy of roles found in the professional context.

Table II shows a number of the differentiating phrases used in the graduate attribute definitions. In each and every case, the connotations of the words imply the superiority of the engineer qualification. In this context, the implied hierarchy is effectively a nested logical inclusion: the set of problems solved by the engineer graduate (complex with wide-ranging issues, etc.) surely incorporates the problems solved by the technician graduate (well-defined with several issues). One might easily conclude, then, that the engineer graduate automatically has the capabilities of the technician and technologist graduates.

Clearly such a conclusion is in error, as the practical and applied aspects of the technician qualification impart skills and knowledge of engineering applications that are unlikely to be included in an engineer qualification. But those aspects of engineering work where the technician graduate should surpass the engineer graduate are either excluded or stated in a manner that reinforces the hierarchy.

In addition to the phrasing of the graduate attributes, one often finds that the qualification structures and admission standards in different parts of the world also suggest a hierarchy. Due to the heavier emphasis on abstract mathematics and science in most engineer qualifications, entrance requirements are frequently stricter than for technologist qualifications. A brief examination of Table I also shows that the duration of engineer qualifications is frequently longer than for the other categories. These effects combine to suggest that the technologist qualification is "easier," and that the "harder" engineering qualification must be superior.

The impression of academic superiority is detrimental not to students, who would be best served by selecting the qualification for which they are best suited. It is also detrimental to employers, who may not have direct experience with one of the roles and judge potential applicants based on the perceived hierarchy rather than on their company's needs.

V. EFFECTS OF THE HIERARCHY

The perceived hierarchy can have a significant effect on graduate opportunities. A 2012 study by Land [11] surveyed 200 US engineering companies, and found that most companies hiring both technologist and engineer qualification graduates do not find a significant difference in ability or value between the two over time. Graduates with different types of engineering qualifications were often placed in positions that made use of their hands-on skills or abstract thinking ability. Particular job titles (e.g., "Engineer," "Engineering Trainee") were frequently given to candidates with either qualification. Additionally, respondents noted that technologist graduates were frequently productive sooner and that engineer graduates approach problems from underlying principles; both indicate an appreciation of the strengths of each type of candidate.

More significant and concerning, however, were the responses from the companies who do *not* hire applicants with technologist qualifications. Those employers cited a lack of skills and knowledge as the primary reasons for avoiding technologist graduates, despite the clear feedback from other companies noting the different but equally valuable skills and knowledge possessed by each type of graduate. As Land summarizes:

> If there is news in these responses, it is that there is no news. These data seem to reflect the generally held perception by many that engineering technology graduates are "engineering light" graduates. Other data reported here may well belie this perception, but clearly the perception persists. [11]

Another place where the hierarchy merits investigation is at the academic source: how do students and educators perceive the difference? However, as indicated by the results in [11], an academic environment involving only one role is likely to have little insight into the other role. Rather few academic institutions worldwide offer both engineering and technologist/technician qualifications, but those that do can provide unique perspectives on the differences and similarities between the types of graduates.

A recent study [12] of student identity was conducted at the Dublin Institute of Technology, which offers both three-year technologist and four-year engineer qualifications. The study pursued several methodologies simultaneously, including staff interviews, student surveys, and a comparison of approaches to design. Overall, the results neatly support the findings in [11]. Some indicative findings include:

- A significant number of students from both qualifications were unable to clearly distinguish between the engineer and technologist roles.
- Engineer students were more likely to associate with design tasks and new solutions/things, while technologist students found affinity with system integration and practical tasks.
- The same findings were postulated during staff interviews and observed during a small design project case study.

Another study [13] from Southern Polytechnic State University (SPSU) in Georgia, USA, conducted an anonymous survey followed by semi-structured interviews with staff members about the relationship between the engineer and technologist qualifications. Both types of qualification are offered at SPSU, and both are a four-year degree. Unlike most US institutions offering both types, SPSU has a long history of offering a technologist qualification and has only recently introduced an engineer qualification. The study discusses the power dynamics and struggle to define a conceptual boundary between the two programs, but significantly notes that the technologist faculty views the technologist qualification and graduates as equivalent if not superior to the engineer qualification and graduates. Some particularly relevant comments from faculty members include: "Honestly, most faculty in the programs couldn't really tell you the difference between the programs," and "[our technologist graduates] have been working as engineers in industry for decades." Both indicate a somewhat alarming lack of clarity as to the purpose and distinction between the two roles, and that lack of clarity has a significant impact on the design of the academic programs.

VI. Re-envisioning the Roles

Due to all the perceptions and attitudes described above, there is a need to revise the way in which the three engineering roles are framed. An appropriate presentation must highlight the differences in focus and identify areas of competence without implying an overall superiority or inferiority of any particular role. Rather, an improved model should suggest the superiority of each role in the suitable aspects of engineering activity. Additionally, the framework should specifically highlight the flexibility of graduates and the overlapping areas of work and expertise. Here, we utilize the popular Conceive-Design-Implement-Operate (CDIO) framework [14] as the basis of identifying the dominant roles in different portions of the engineering process. In doing so, we avoid the inherently relativist definition of the technologist and technician roles noted in previous sections.

The CDIO framework was devised around the turn of the century to help design engineering curricula to meet the changing expectations of graduate engineers. Formulated and expanded in [14], the CDIO approach aims to train engineering graduates in the fundamental steps of an engineering development process through structured design activities and more. The fundamental appeal of the CDIO framework is the consistent alignment of student learning activities with the engineering processes encountered in industry. Though the vast majority of CDIO consortium partners offer engineer qualifications, some previous studies have used the CDIO framework to help define and evaluate the technologist qualifications and role. Notably, the University of Houston uses CDIO to underpin their four-year engineering technologist program [15], and the program leaders have also used the

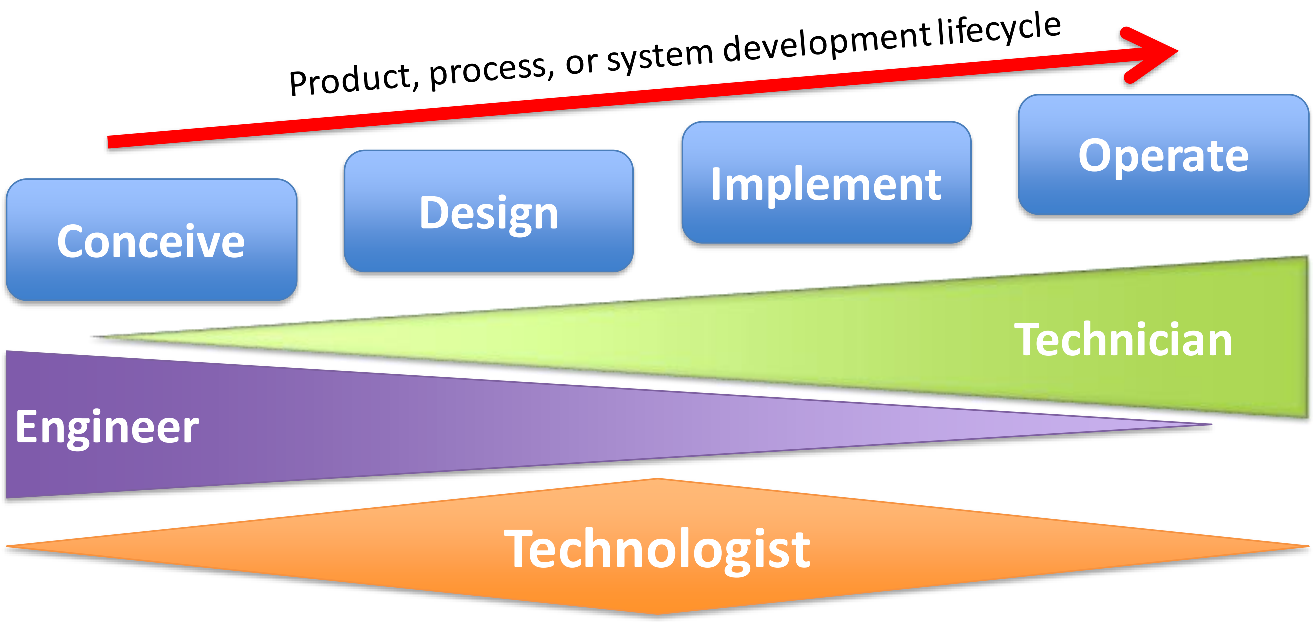

Fig. 5. Each of the three engineering roles has an area of dominance within the CDIO framework.

CDIO spectrum to highlight the differences between engineering and technologist qualifications. Our model goes further by including the technician role in the spectrum, and utilizing the CDIO framework as the basis for identifying the areas of superior competence of each engineering role.

Fig. 5 graphically illustrates the phases of an engineering product, process, or system lifecycle as described in the CDIO framework, where the thickness each shape indicates the amount of emphasis on a particular phase. Each of the three engineering roles is preeminent in different aspects of the CDIO process, and this preeminence should be incorporated into the qualification structure corresponding to each role. Engineer qualifications emphasize fundamental science and mathematics not by definition, but because an understanding of fundamental principles is important when conceiving an idea and transitioning to a feasible design. Technologist qualifications are (or should be) targeted at the design and implement stages, and that emphasis will produce technologist graduates more capable of implementing designs than their coworkers with engineering qualifications.

It is useful to identify each role with the pair of CDIO stages for which the graduate is best prepared and the transitions between the two. The technologist role and academic qualification are firmly seated in the design-implement stages of the CDIO framework, and should be considered preeminent in the transition between those stages. A technologist qualification should be built around turning designs into practical implementations, and the graduate of a technologist qualification should be (and should be considered to be) superior to graduates of either engineering qualifications or technician qualifications at designing-implementing. Similarly, technician qualification graduates will be best prepared to successfully, accurately, and appropriately implement-operate engineering designs and products. Finally, an engineer-graduate is trained to excel at turning abstract concepts into designs, and is appropriately valued for the ability to conceive-design. Note that we do not necessarily exclude the engineer-graduate from operating, nor the technician-graduate from conceiving of new products and processes. Our framework highlights the emphasis of the academic program and the likely subsequent professional engineering activity, where each engineering role rises to preeminence. However, as with any group made up of individuals, we may expect some to move beyond the focus of their educational training and capably work in another focus area. [15] even asserts (predating and supporting the findings of [11]) that after a few years of working engineer and technologist graduates "gravitate toward the middle section of the spectrum" and "become indistinguishable from each other as they are both involved in the 'functional engineering' tasks."

Our model for situating the three roles is supported by several credible sources. First, note that philosophy behind the models presented earlier is not contradicted. Rather, we present the theory-skill spectrum in terms of the engineering process and in doing so preserve the importance of each role. Also, various descriptions of the engineering roles fit seamlessly into the model in Fig. 5. The "tapering" role of the engineer is clear from the description of what engineers do in the introduction to the CDIO approach: engineers "help create the concept," "design products processes and systems," "lead, and in some cases, execute the implementation," "consider and plan for the operation" [14, pp. 2]. There is a tangible decrease in involvement from active, full participation in conception and design to an almost cursory consideration of operation. In addition to the previously discussed [15], the following description of a technologist clearly supports the model.

> The essence of a technologist is the mastery of a whole field with a broad and deep understanding of the technology—the processes, systems, tools, and techniques necessary to construct, modify, innovate, operate and maintain the engineering design…. The technologist … is positioned in the "sweet spot" between the engineer and the technician/skilled craftsman. [16]

We might argue, however, that the description of from [16] may be encroaching on the technicians' area of superiority. Literature regarding the specific role of technicians is sparse, as (recalling the chronology in Fig. 1) most early discussions combined the technologist and technician roles into one category. Later, as the roles became formalized, efforts were primarily focused on distinguishing the technologist from the engineer rather than focusing on the technician. However, as the technician role is agreed to be part of engineering work, technician activities must fall at the most application-focused end of the framework, and the experienced technician will surely excel at the implement-operate stages beyond the design-oriented coworkers.

VII. THE FUTURE OF THE ENGINEERING TEAM

Technology and the engineering workforce that drives it are moving forward an ever-increasing pace. The structure of the engineering team constantly adapts to the nature of the product, process, or system under development. Already, different fields of engineering are following dramatically different development models, some exclusively software-based and some requiring extensive physical engineering work. As modern technology change the way goods are manufactured and services delivered, one thing is certain: change is coming.

Engineering work inevitably leads to both interdisciplinary and multi-role tasks. This was highlighted in a survey of Australian more than 1200 technical workers in the 1980s, reported in [5]. The study found a correlation between qualification level and task level, but also found almost all types of engineering work were being performed by some workers of every qualification level [5, pp 132-135]. The older findings mirror the results of [11] referred to previously, suggesting that the career paths of technologists and engineers converge and intermingle as experience begins to overshadow educational background. One should expect this pattern to accelerate as shifting disciplinary boundaries make flexible engineering workers increasingly valuable.

Engineering authorities should look carefully to the future of their industries, aligning (and if necessary redefining) the engineering roles to balance flexibility with professional competence and responsibility. More importantly, educational institutions should revisit the purpose and approach of the engineering qualifications, removing or updating outdated definitions and demarcations wherever possible. The CDIO-based model for engineering teams presented here provides useful guide for identifying the engineering roles, and will continue to do so even when those roles shift and adapt to the needs of future engineering projects.

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